

Checkpoint and Restart Procedures for Single and Multi-stage  
Structural Model Analysis in NASTRAN/COSMIC on a CDC 176

George H. Camp and Dennis J. Fallon  
David Taylor Naval Ship Research and Development Center

Summary

The Underwater Explosions Research Division (UERD) of David Taylor Naval Ship Research and Development Center (DTNSRDC) makes extensive use of NASTRAN/COSMIC on a CDC 176 to evaluate the structural response of ship structures subjected to underwater explosion shock loadings in the time domain. As relatively new users, UERD research engineers have encountered many problems on various levels during the analysis process and have found it necessary to utilize the checkpoint/restart feature of NASTRAN/COSMIC. As the USER'S Manual is vague on the subject of checkpoints/restarts, a set of working procedures were developed for the implementation of the checkpoint/restart feature in the transient analysis (Rigid Format # 9) of single stage structural models and multi-stage substructure models. These working procedures are the subject of this paper. Examples are illustrated in the Appendix to highlight these procedures for a CDC 176 computer.

Introduction

NASTRAN/COSMIC was designed to run large problems usually requiring lengthy execution times and/or large memory allocations. User errors are common. Operator, hardware, or system failures resulting in the abnormal termination of a problem are not entirely uncommon, even with the best of computer systems. Due to machine and code dependent parameters, the termination of a run because of exceeded time and/or memory allocations is quite possible.

To prevent costly loss of information generated immediately prior to the point of termination and/or to allow added flexibility as well as efficiency in the solution process, the user is encouraged to utilize the checkpoint/restart feature available in NASTRAN/COSMIC.

The checkpoint/restart feature of NASTRAN/COSMIC was designed to allow the user to checkpoint a NASTRAN run and later restart it by executing only those modules needed for completion of the solution. The restart deck submitted to NASTRAN may include corrections to erroneous or omitted data in the original checkpoint run, additional data entries, or may simply consist of the original data deck in cases where the program terminated abnormally due to a system failure. Unfortunately, the NASTRAN User's Manual is not entirely clear on the procedures for checkpointing and restarting problems, particularly those for

multi-stage substructure model analysis. Hence, a few points in the procedure are worthy of discussion.

#### Checkpoint Procedure

The checkpoint/restart feature is applicable to the analysis of single stage structural models as well as multi-stage substructure models, and the procedure for checkpointing the problems is identical.

Outlined in Example 1 of the Appendix is a listing of the job and executive control decks for a single stage model and a multi-stage substructure model analysis problem. These examples are accompanied by a brief explanation of the additional and pertinent commands necessary for the execution of the checkpoint procedure on a CDC 176 computer.

The user may find it difficult to predict the memory and time requirements of large problems without some knowledge developed through experience. There are methods available which are somewhat dependable for the estimation of these parameters [1]. However, these methods can not guarantee the successful completion of the job, nor, in some cases, are these procedures easily implemented. If the problem warrants it, the time and memory limits may be set at the maximum values [2], but doing so has the trade-off of changing the priority of the job. This will be accompanied by a delay in the execution of the problem. In many instances at the DTNSRDC computer facility it is wise to schedule blocktime [2] for the solution of large problems, thus reducing the cost of execution. However, the job is still dependent on the system whose failures are not easily controlled or anticipated.

In the case of substructure modeling, the user has the option of checkpointing a Phase One run for subsequent Phase Three restarts. It is UERD's experience that in most cases this is neither economical nor advantageous. The disadvantage is that it requires more computer time to execute the checkpointed Phase One run, more cost due to storing the large new problem tape (NPTP) and requires more computer time due to increased I/O in the Phase Three run.

#### Restart Procedure

Assuming the checkpointed solution run terminated abnormally due to one of the afore mentioned conditions, and both the "NPTP" and "PUN" files were created and successfully stored, recovery of the job consists of a few simple modifications to the original input deck and resubmitting it for execution. The modifications consist of: 1) attaching the "NPTP", 2) merging the restart dictionary into the executive control deck, 3) making any corrections to the case control or bulk data decks and 4) including an "ALTER" if the problem is a substructure model analysis.

Outlined in Examples 2 and 3 of the Appendix are listings of the job and executive control decks required for the unmodified restart (no changes) of single stage structural model and multi-stage substructure model analysis problems. Each of these examples are followed by a brief description of the additional and pertinent commands.

If the termination is due to error(s) in the case control or bulk data, the effective changes should be included in the restart run. For case control errors, the correction is included or replaces the erroneous command. If errors in the bulk data exist, only the corrections need to be included and the rest of the bulk data deck is omitted. Adjustments to time and memory limits may be required depending on their values in the checkpointed run and the point at which the job terminated in the solution sequence. The point of termination is determined by examining the dayfile messages or by inspecting the checkpointed DMAP sequence list which appears in the PUN file or restart dictionary (the last sequence reentered is the point of termination).

For most large problems in which time or memory allocations were insufficient, the program may terminate in the dynamic loop. For substructure analysis problems which terminate within the dynamic loop, restarting the problem requires the addition of an ALTER statement which enters the DMAP sequence immediately after the last sequence checkpointed (see Example 3, statement 20). The purpose of this ALTER is to regenerate substructure control deck information required for recovery of the solution vector which is not checkpointed by NASTRAN/COSMIC. This problem occurs at executive decision making levels in the solution process and can only be remedied by the inclusion of an ALTER statement at this time. Future code changes may correct this problem.

#### Concluding Remarks

This paper illustrates working procedures for application of the checkpoint/restart feature to the transient analysis using NASTRAN/COSMIC. The importance of the substructure modeling technique has grown in proportion to the growth in complexity of problems UERD research engineers are tasked to solve. Just as the complexity of problems increases, so does the need for flexible and efficient solution techniques. The checkpoint/restart feature of NASTRAN/COSMIC was designed to accomplish this objective. Following the procedures illustrated in this paper will aid new users to become more proficient in the use of this powerful tool.

## APPENDIX

Example # 1 : Checkpointing of direct transient analysis of single stage or multi-stage structural models.

```
1.    CS^^,CM260000,T50,P3.
2.    CHARGE,CS^^,XXXXXXXXXX.
3.    LIMIT,7777.
4.    REQUEST,OUT,*PF.
5.    REQUEST,NPTP,*PF.
6.    REQUEST,PUN,*PF.
7.    MSACCES,^^^^.
8.    ATTACH,NASTRAN.
9.    BEGIN,NASTRAN,NASTRAN,260000,,OUT,PUN.
10.   EXIT,U.
11.   CATALOG,OUT,OUTPUT,ID=CS^^.
12.   CATALOG,NPTP,ID=CS^^.
13.   CATALOG,PUN,RESTDICTNRY,ID=CS^^.
14.   EOR
15.   NASTRAN TITLEOPT=-2,SYSTEM(71)=1,FILES=NPTP ??
16.   ID FOREMAST,ANALYSIS
17.   APP DISP
18.   SOL 9,0
19.   TIME 50
20.   DIAG 8,14,22
21.   CHPNT YES
22.   CEND
23.   TITLE .....
      *
      *
      ETC.
```

\*Note: CASE CONTROL AND BULK DATA DECKS AS USUAL.

### Description of Commands

1. The central memory "CM260000" and total job time "T50" resources allocated here may be the cause of an abnormal termination and may need to be adjusted for the restart run depending on the size of the problem and how much of the solution was completed [2]. Close inspection of the dayfile and output messages may show the reason(s) and point of termination. When the job aborts due to exceeding the CPU time limit, the system will allow time to catalog and unload files, so the "NPTP" and "PUN" files will be available for restart.

3. The amount of mass storage which may be used at one time is specified via the "LIMIT" card [2]. If the mass storage is inadequate the job will terminate. Again, the need to increase this parameter will be determined by the size of the problem and how much of the solution was completed prior to termination.

5.,6. To catalog these files, which are essential to restart the problem, they must be requested as permanent files. The "NPTP" (new problem tape) is the file that contains the information generated prior to termination needed to complete the solution. The "PUN" (punch output file) is a file containing the checkpoint dictionary (a complete listing of all DMAP sequences that were executed and checkpointed). The checkpoint dictionary must be edited to remove all "EOR" messages that appear, then merged in the executive control deck of the restart run. The creation of these files is mandatory.

9. The files "OUT" and "PUN" should appear as parameters in this statement for definition and creation.

12.,13. The files "NPTP" and "PUN" must be catalogued for retrieval.

15. Among the parameters utilized, the user is urged to set "SYSTEM(71)" to "1", which will suppress some of the information routed to the dayfile. This information is, however, printed in the output file. This reduces the chance of the program terminating due to exceeding the dayfile message limit but still provide the information which may be useful in tracking other errors. The "NPTP" must be specified as an executive file via "FILES=NPTP" on the NASTRAN card.

16. The problem ID should be specified as per instructions in the User's Manual for the checkpoint run [3]. This is due to the format requirements of the restart card in the checkpoint dictionary. Incorrect format will cause difficulty in the restart process.

19. This command specifies the maximum time allotted to NASTRAN for problem execution. If the amount specified is inadequate the job will terminate, producing fatal error messages in the output. The user will then be required to submit a restart deck to recover the job. The time may need to be increased upon restart depending on the point of termination. The time required for NASTRAN execution is less than the total job time required.

21. This command initiates the checkpoint process. It is mandatory for checkpointing the problem [3].

Example # 2 :Unmodified restart of direct transient analysis of single stage structural model

```

1.    CS^^,CM260000,T500,P3.
2.    CHARGE,CS^^,XXXXXXXXXX.
3.    LIMIT,7777.
4.    REQUEST,OUT,*PF.
5.    MSACCES,XXXXX.
6.    ATTACH,NASTRAN.
7.    ATTACH,OPTP,NPTP,ID=CS^^.
8.    BEGIN,NASTRAN,NASTRAN,260000,,OUT.
9.    EXIT,U.
10.   CATALOG,OUT,OUTPUT,ID=CS^^.
11.   EOR
12.   NASTRAN TITLEOPT=-2,SYSTEM(71)=1,FILES=OPTP
13.   ID A1234567,B7654321
14.   APP DISP
15.   SOL 9,0
16.   TIME 50
17.   DIAG 8,14,22
18.   RESTART A1234567,B7654321 , 9/17/86, 48570,
      1,    XVPS      ,    FLAGS = 0,    REEL = 1,    FILE = 5
      2,    REENTER AT DMAP SEQUENCE NUMBER    6
      3,    GPL      ,    FLAGS = 0,    REEL = 1,    FILE = 6
      4,    EQEXIN   ,    FLAGS = 0,    REEL = 1,    FILE = 7
      5,    GPD      ,    FLAGS = 0,    REEL = 1,    FILE = 8
      6,    CSTM     ,    FLAGS = 0,    REEL = 1,    FILE = 9
      7,    BGPDT    ,    FLAGS = 0,    REEL = 1,    FILE = 10
      8,    SIL      ,    FLAGS = 0,    REEL = 1,    FILE = 11
      9,    XVPS     ,    FLAGS = 0,    REEL = 1,    FILE = 12
     10,    REENTER AT DMAP SEQUENCE NUMBER    7
     11,    BGPDT    ,    FLAGS = 0,    REEL = 1,    FILE = 13
      .
      .
      .
      .
     203,    TOL      ,    FLAGS = 0,    REEL = 1,    FILE = 85
     204,    XVPS     ,    FLAGS = 0,    REEL = 1,    FILE = 86
     205,    REENTER AT DMAP SEQUENCE NUMBER   125
     206,    PDT      ,    FLAGS = 0,    REEL = 1,    FILE = 87
     207,    XVPS     ,    FLAGS = 0,    REEL = 1,    FILE = 88
    $      END OF CHECKPOINT DICTIONARY
19.   CEND
20.   TITLE = .....
      *
      *
      ETC.

```

\*Note: IF NO EFFECTIVE CHANGES, CASE CONTROL DECK IDENTICAL TO CHECKPOINT RUN AND BULK DATA DECK OMITTED.

### Description of Commands

1. This particular problem is the restart of the checkpointed previous example. The problem aborted because the time allocated (T50) was not sufficient for completion of the run. Although the checkpoint dictionary indicates that the program was almost completed (the last sequence reentered was 125), the time limit was extended to "T500" for restart. This amount would have been sufficient for the run to be completed in the checkpoint phase.

3. This command remains unchanged.

7. The "NPTP" is made available to NASTRAN via this statement, and must be renamed as the "OPTP" (old problem tape). This command is mandatory for restarting the problem since the NPTP/OPTP contains the information required by NASTRAN to continue the solution sequence.

12. As previously mentioned, "SYSTEM(71)" is set to "1" and the "OPTP" is specified as an executive file.

16. The NASTRAN execution time, "TIME 50", is deemed adequate and remains unchanged.

18. This is a partial listing of the checkpoint/restart dictionary which is contained in the PUN file. The first card shown is the restart card [3]. This card identifies the problem as a restarted job. The first entry is the ID of the checkpointed problem. This entry is compared to the NPTP/OPTP to verify that it corresponds to the problem being restarted. The cards which follow indicate the DMAP modules which were executed and checkpointed. As can be seen from this deck, the last successfully completed and checkpointed sequence was DMAP module 124. Number 125 was reentered, but checkpointing was not completed. Therefore, sequence number 125 is the point at which NASTRAN will pick up the solution process. This complete file is mandatory.

Note: The case control deck is required for restarting the job, but the bulk data deck may be omitted if there are no changes. Also, a restart run may be checkpointed as any other problem which is eligible for checkpointing, but the user should weigh the benefits of doing so to keep computer costs minimal.

Example # 3 : Unmodified restart of direct transient analysis of multi-stage substructure model

```

1.  CS^^,CM377700,T400,P3.
2.  CHARGE,CS^^,XXXXXXXXXX.
3.  LIMIT,10000.
4.  REQUEST,OUT,*PF.
5.  MSACCES,XXXXX.
6.  MSFETCH,OTPT,ID=CS^^.
7.  ATTACH,NASTRAN.
8.  ATTACH,SOFA,ID=CS^^.
9.  BEGIN,NASTRAN,NASTRAN,377700,,OUT,PUN.
10. EXIT,U.
11. CATALOG,OUT,TESTOUT,ID=CS^^.
12. EXTEND,SOFA.
13. EOR
14. NASTRAN TITLEOPT=-2,SYSTEM(71)=1,FILES=OTPT
15. ID AFTMODEL,ANALYSIS
16. APP DISP,SUBS
17. SOL 9,0
18. TIME 150
19. RESTART AFTMODEL,ANALYSIS , 8/21/86,      76863,
    1,      XVPS      ,      FLAGS = 0,      REEL = 1,      FILE = 6
    2,      REENTER AT DMAP SEQUENCE NUMBER      6
    3,      GPL      ,      FLAGS = 0,      REEL = 1,      FILE = 7
    4,      EQEXIN    ,      FLAGS = 0,      REEL = 1,      FILE = 8
    5,      GPDT      ,      FLAGS = 0,      REEL = 1,      FILE = 9
    6,      BGPDT     ,      FLAGS = 0,      REEL = 1,      FILE = 10
    7,      SIL      ,      FLAGS = 0,      REEL = 1,      FILE = 11
    8,      GE3S      ,      FLAGS = 0,      REEL = 1,      FILE = 12
    9,      GE4S      ,      FLAGS = 0,      REEL = 1,      FILE = 13
   10,      DYNs      ,      FLAGS = 0,      REEL = 1,      FILE = 14
   11,      XVPS      ,      FLAGS = 0,      REEL = 1,      FILE = 15
   12,      REENTER AT DMAP SEQUENCE NUMBER      5
   13,      XVPS      ,      FLAGS = 0,      REEL = 1,      FILE = 16
      .
      .
      .
      .
      .
   203,      REENTER AT DMAP SEQUENCE NUMBER      125
   204,      PDT      ,      FLAGS = 0,      REEL = 1,      FILE = 75
   205,      XVPS      ,      FLAGS = 0,      REEL = 1,      FILE = 76
   206,      REENTER AT DMAP SEQUENCE NUMBER      126
   207,      UDVT      ,      FLAGS = 0,      REEL = 1,      FILE = 77
   208,      XVPS      ,      FLAGS = 0,      REEL = 1,      FILE = 78
$ END OF CHECKPOINT DICTIONARY
20. ALTER 126 $
21. SGEN      CASECC, GEOM3, GEOM4, DYNAMICS/CASESS, CASEI,
    DUMA1, DUMA2, DUMA3, DUMA4, DUMA5, DUMA6, DUMA7,
    DUMA8/1/*TOTAL*/DUM1/DUMN $
22. ENDALTER
23. DIAG 8,14,22

```



```

24. CEND
25. SUBSTRUCTURE PHASE2
26. PASSWORD=XXXXXX
27. SOF(1)=SOFA,9000
28. OPTIONS K,M,P
29. SOFPRINT TOC
30. SOLVE TOTAL
31. RECOVER TOTAL
32. PRINT MARTIN
33. SOFPRINT TOC
34. ENDSUBS
35. TITLE=.....
    *
    *
    ETC.

```

\*Note: IF NO EFFECTIVE CHANGES, CASE CONTROL DECK IDENTICAL TO CHECKPOINT RUN AND BULK DATA DECK OMITTED.

#### Description of Commands

1. This particular problem required the maximum amount of core memory available "CM377700" [2]. The time allotted here was reduced from the original value specified because of the point at which the program terminated. The solution vector was completed but never recorded in the "SOF" (substructure operational file), therefore, the restart was performed to simply retrieve the solution from the NPTP/OPTP and store it in the "SOF" for use in Phase Three. This procedure required a considerable amount of memory, but not much time.

3. The original problem did not allocate ample mass storage (LIMIT 7777.) which was the cause of the program termination. The limit was extended to the maximum for the restart [2].

6. Due to the size of the NPTP/OPTP, it was placed in mass storage by the checkpoint run. This command retrieves the OPTP from mass storage for restart.

19. This is a partial listing of the checkpoint dictionary for this problem (again found in the PUN file). This list indicates that the last DMAP module checkpointed was sequence number 125. Therefore, the first module flagged for execution in the restart phase is number 126 and the ALTER occurs at this point.

20.-22. This ALTER regenerates information necessary for recovery of the solution vector. SGEN is a structurally oriented functional module producing data blocks as required for the solve operation [4]. NASTRAN does not checkpoint some of the output data blocks from this module which are necessary to the solution process. Therefore, the user must regenerate these data blocks (CASESS and CASEI) for restarting the problem. The remaining output data blocks and parameters need not be regenerated and are given dummy labels. These cards are mandatory for restart of substructure analysis problems.

## References

- 1.) Everstine, G. C., and Hurwitz, M. M., "Nastran Theory and Application Course Supplement". David Taylor Naval Ship Research and Development Center, Bethesda, Md., Report DTNSRDC/ CMLD-81-05, Feb. 1981.
- 2.) Sommer, D. V., "Computer Center Introductory Reference Manual for CDC Cyber". David Taylor Naval Ship Research and Development Center, Bethesda, Md., Report DTNSRDC/ CMLD-84-09, May 1984.
- 3.) "The Nastran User's Manual", COSMIC, Athens, Ga., NASA SP-222, Dec. 1980.
- 4.) "Nastran Programmer's Manual", COSMIC, Athens, Ga., NASA SP-223, Dec. 1979.